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Effect of wire mesh on the strength of R.C.C. beams repaired using ferrocement layers

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ABSTRACT*: *Ferrocement, a thin element is used in building construction as well as a repair material. Here an experimental investigation on ferrocement performance for repairing of RCC beam is presented. Three set RCC beams of the same dimension (width 4″, thickness 6″ and span 5.5′) are tested up to ultimate load by one point loading system as a simply supported beam. These beams are addressed as BN-1.1, BN-1.2, BN-1.3, BN-2.1, BN-2.2, BN-2.3, BN-3.1, BN-3.2 and BS-3.3 according to their set. After testing of beams BN-1.1, BN-1.2 and BN-1.3 are repaired by 0.5 inch ferrocement layer on three sides. The Beams BN-2.1, BN-2.2, BN-2.3 are subjected to two layers of ferrocement on the bottom of thickness 1 inch and only one layer in a two sides. And another three beams of BN-3.1, BN-3.2, BN-3.3 are surrounded by total 1 inch ferrocement layer on three sides. Then they are verified again. A comparison has been made on cracking load, ultimate load and deflection between the normal beams and repaired beams. The study also represents performance of beam sets according to their different layer by graphical representation. From this paper, we can understand that the beams of bottom two layers ferrocement overlay (repairing) give comparatively good performance.

Keywords: Ferrocement, beam, cracking load, ultimate load, repairing, deflection.

I. INTRODUCTION

As Bangladesh is a poor country, the cost of building retrofitting is a major consideration. Due to modernization of buildings, it is sometimes desirable to remove supporting walls or individual supports, leading to the need for local strengthening. Retrofitting is the process of introducing specific elements or features into an existing structure so as to improve its resistance against natural disasters like earthquakes and cyclones. And in another word repairs are taken up on damaged buildings to restore loss of strength after a disaster. The various retrofitting techniques are exist include steel plate bonding, polymer injection followed by concrete jacketing, use of advanced composite materials like FRP, Ferro cement etc.

External bonding of steel plates to damaged reinforced concrete structures is one of these methods and has been shown to be quite an efficient and a well- known repair or strengthening technique. It has been largely studied in France (L'Hemite, 1967), (Bresson, 1971) and intensive research performed in the beginning of the eighties (theillout, 1983) results in French rules concerning the design of those structures (SOCOTEC, 1986). [RF11]

The use of composite materials represents an alternative to steel as it can avoid the corrosion of the plate. FRP materials are also very lightweight, have a high strength to weight ratio and are generally resistant to chemicals. The price of these materials, especially of Carbon Fibre Reinforced Plastics (CFRP), could represents a drawback but the ease in handling the material on construction sites, due to the light weight, helps to reduce labor costs. This technique has been largely investigated especially in Switzerland (Meier, 1995) where existing structures have been retrofitted using epoxy-bonded composite materials. Fibre Reinforced Polymers (FRP) are been extensively used as external wraps for the structural strengthening and rehabilitations of buildings.

Ferrocement is a composite material consisting of cement mortars and reinforcements in the form of multiple layers. The ferrocement have been in housing unit, water tanks and roofs because of their excellent load deformation, crack control and impact resistance. The composite result in better structural performance than that of individual one.

Reinforcement concrete beam is the most important integral part of a structure. If the strength of the beam built as designed, could be predicted accurately and if the loads and their effects were known accurately, safely could be measured by providing a carrying capacity just barely in excess of the known loads. However, there are a number of sources of uncertainty in the analysis, design and construction of the reinforced concrete beam. As poor country like Bangladesh, it is not possible to replace all the older structures which were failed by new ones. But experimental investigation shows that it is more feasible to rehabilitate them of load carrying capacity of beam. From both the economical and strength point of view to our country, it can be designed such a beam which will be less

in cost, strong enough to resist the failure resulting from the external, internal load etc. To meet this

condition the reinforcement concrete beam can be needed to be repair by using ferrocement overlay. In our experiment first normal R.C.C. beam is stressed, then the damaged beam is repaired with ferrocement layer in different thickness and again stressed. By using ferrocement layer on damaged beam can be obtained a reasonable strength.

1.1 Aim of this study

The vast majority of structural member is beam. The main objective of this study is to make a comparison on strengthening of reinforcement concrete beam using ferrocement overlay. The objectives of this study are outlined below:

1) To compare the strength, first cracking load, ultimate load, deflection between the beam before and after repair with ferrocemnent
2) To show the strength of different type of ferrocement layer.
3) To give the damaged beam a reasonable strength.

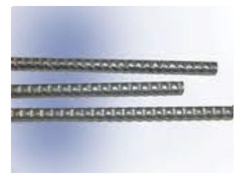
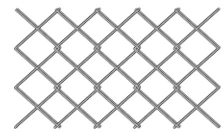
II. History of Ferrocement

Ferrocement is the name given by Italian Professor Pier Luigi Nervi to a thin slab of mortar reinforced with superimposed layers of wire mesh and small diameter bars. The result is a product with a high degree of elasticity and resistance to cracking which can be cast without the use of formwork. Nervi successfully proved on many jobs the remarkable strength and lightness of this method of construction and its great adaptability to any shape. The end result of Nervi's experiments was a medium in which the thickness of a finished slab was only a very little greater than that of the assembled layers of mesh, the difference being only as much as was necessary to provide adequate cover for the steel. This ferrocement was found on testing to have very little in common with normal reinforced concrete, however, since it possesses the mechanical characteristics of a completely homogeneous material. ACI Committee 549, Ferrocement and Other Thin Reinforced Products, was organized in 1974 and was given the mission to study and report on the engineering properties, construction practices, and practical applications of ferrocement and to develop guidelines for ferrocement construction.

III. PROPERTIES OF CONSTRUCTION MATERIALS

Any material which has got an application in engineering constructions is termed engineering material. A quality that defines specific characteristics of a material is termed as a property. The properties of a material provide a basis for predicting its behavior under various conditions. And the properties of the used materials have been described below:

Table 1: Basic Properties of required Materials

SL No.	Used Materials	Properties (From test results)	Figure
1	Steel	Bar type: Deformed bar Bar diameter: 1/2” and ″ Average yield strength: 39.47 ksi Bending: ok	
2	Wire Mesh	Mesh type: Wire size: 22 gauge Contour size: 0.5″ (both way) Mesh strength: 35.12 ksi	
3	Cement	Compressive strength: 23.5 ksi (28 days)	
4	Sand	FM: 2.98 Water content: 0.5% Density: 101.50 pcf Specific gravity: 2.59	
5	Water	Ordinary potable drinking water free from organic matter, silt, oil, sugar, chloride and acidic material was used for mixing.	

IV. Methodology

4.1 Test specimen

To carry out the investigation, three set beams of length 6ft-8in, width 4in and thickness 6in, reinforced with two bars of #4 in tension and two bars of #3 in compression. Then these three set beams were subjected to approximately ultimate load. After damaging these beams were repaired by ferrocement layer in three different thicknesses. First set of beams BS-1.1, BS-1.2 and BS-1.3 were subjected to only one layer of ferrocement surrounding it's three sides of thickness 0.5 in. In second set of beams BS-2.1, BS-2.2 and BS-2.3 two layers of

thickness 1 in is provided on the bottom of the beam and one layer of total thickness 1 in is provided on two sides of the beam. Third set of beams BS-3.1, BS-3.2 and BS-3.3 were subjected two layer of thickness 1 in is provided on the three sides of the beam.

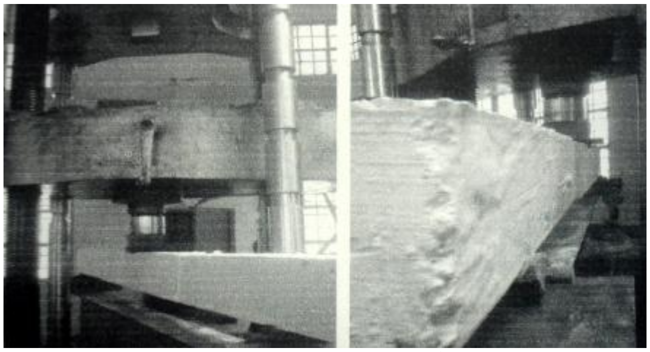


Figure 1: Testing Arrangement of Specimen

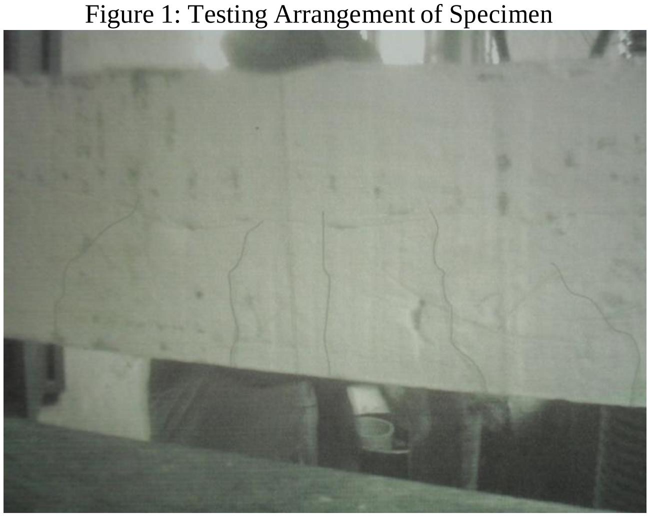


Figure 2: Cracking Pattern of Beam

4.3 Test Procedure

After painting and coating period, all the three set simply supported beams were tested with an effective span of 5.5ft, deflectometer was fixed at mid-point of the beam of its tension face of each specimen as shown in figure 1. A universal testing machine was used to load the specimen. For all the beams deflection at different loads were measured. A deflectometer was put at midsection to measure the deflection of the beam. The beam was subjected to one point loading. The loading is gradually increased from zero until the beam was near to fail. Deflectometer reading was record for each loading. Increments of load were decided so that a representative load-deflection curve could be realized. The cracked beams were than repaired with ferrocement layer and further tested. The cracking pattern of beam is shown in figure 2.

4.4 Repairing Process

At first the surface of beam is cleaned. After cleaning the surface, the cement slurry is applied as bonding agent to the surface of beam. After the application of bonding agent repairing of beam is done by applying ferrocement layer at different layer at different orientation. Then after 7 days curing with same procedure as of control beam, testing of beam was done in order to calculated ultimate and corresponding deflections.

V. TEST RESULT

During testing we are recorded different cracking loads with three corresponding deflection. We also recorded the ultimate load of the beams and their corresponding deflection. To know the comparison between the normal beam and repaired beam first we have to make a table showing the loads and corresponding deflection. The tables are showed below:

Table 2: Results from cracking loads and Ultimate loads with Deflections of Beam Set 1 (without ferrocement)

Beam Set 1						Average	
BN-1.1		BN-1.2		BN-1.3		Ultimate Loads (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0	5.00	0.679
2.45	0.034	2.50	0.035	2.55	0.033		
4.10	0.090	4.00	0.089	3.89	0.087		
4.88	0.240	4.90	0.236	4.92	0.240		
5.00	0.70	5.00	0.667	5.01	0.670		

Table 3: Results from cracking loads and Ultimate loads with corresponding Deflections of Beam Set 2 (without ferrocement)

Beam Set 2						Average	
BN-2.1		BN-2.2		BN-2.3		Ultimate Load (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0	4.03	0.757
1.30	0.072	1.25	0.079	1.27	0.078		
2.45	0.265	2.50	0.260	2.55	0.255		
3.30	0.560	3.20	0.587	3.25	0.580		
4.09	0.780	4.00	0.790	4.00	0.700		

Table 4: Results from cracking loads and Ultimate loads with corresponding Deflections of Beam Set 3 (without ferrocement)

Beam Set 3						Average	
BN-3.1		BN-3.2		BN-3.3		Ultimate Load (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0	4.53	0.874
2.00	0.070	1.50	0.097	1.40	0.10		
3.20	0.321	3.40	0.311	3.42	0.315		
4.44	0.60	4.30	0.654	4.33	0.655		
4.60	0.867	4.50	0.879	4.50	0.877		

Table 5: Results from cracking loads and Ultimate loads with corresponding Deflections of Beam Set 1 (with ferrocement)

Beam Set 1						Average	
BN-1.1		BN-1.2		BN-1.3		Ultimate Load (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0	2.483	0.997
0.87	0.091	0.88	0.090	0.90	0.085		
0.85	0.50	0.90	0.540	0.92	0.520		
2.11	0.881	2.15	0.860	2.16	0.80		
2.45	0.990	2.50	1.00	2.50	1.00		

Table 6: Results from cracking loads and Ultimate loads with corresponding Deflections of Beam Set 2 (with ferrocement)

Beam Set 1						Average	
BN-2.1		BN-2.2		BN-2.3		Ultimate Load (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0	2.717	0.890
0.95	0.088	0.98	0.087	0.92	0.090		
1.92	0.201	1.90	0.210	1.92	0.208		
2.53	0.649	2.56	0.650	2.55	0.658		
2.70	0.870	2.74	0.880	2.71	0.920		

Table 7: Results from cracking loads and Ultimate loads with corresponding Deflections of Beam Set 3 (with ferrocement)

Beam Set 1						Average	
BN-3.1		BN-3.2		BN-3.3		Ultimate Load (kips)	Maximum Deflection (inch)
Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)	Load (kips)	Deflection (inch)		
0	0	0	0	0	0	3.173	0.753
1.03	0.077	1.00	0.076	1.05	0.076		
1.98	0.114	2.00	0.115	2.01	0.112		
3.00	0.557	3.10	0.567	3.05	0.566		
3.15	0.750	3.20	0.750	3.17	0.760		

5.1 Graphical Representation

The graphical representation of the beams performance is indicated that the load Vs deflection curve. This curve is very important to know the rate of increasing strength before and after repairing with ferrocement layer. In our experiment, we get the normal beam data and different ferrocement layered beam data. By these data, we made the graph for three set beam with and without ferrocement.

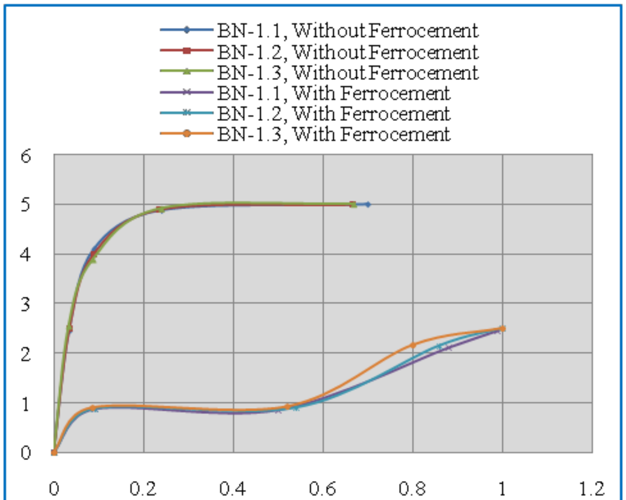


Fig 3: Load (kips) Vs Deflection (inch) Curve of Beam Set 1

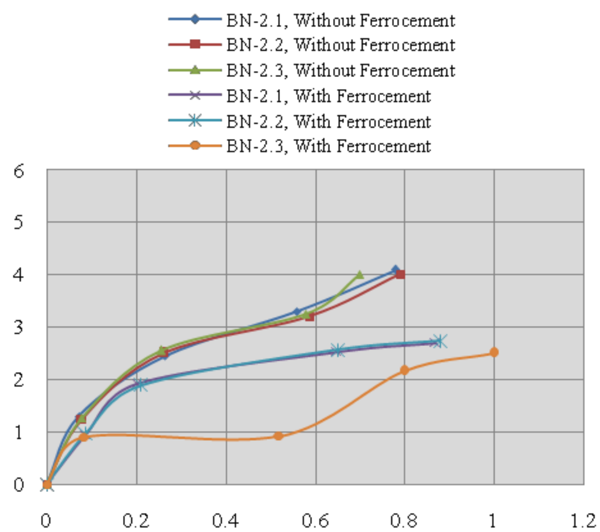


Fig 4: Load (kips) Vs Deflection (inch) Curve of Beam Set 2

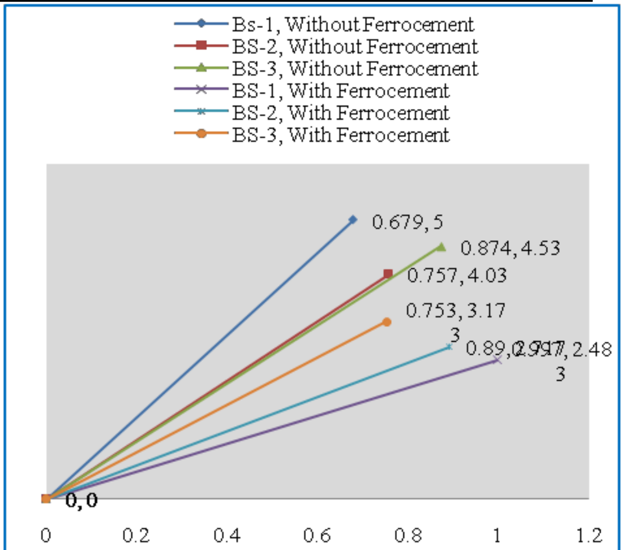


Fig 6: Average Ultimate Load (kips) Vs Average Maximum Deflection (inch) of Beam Set 1,2 & 3

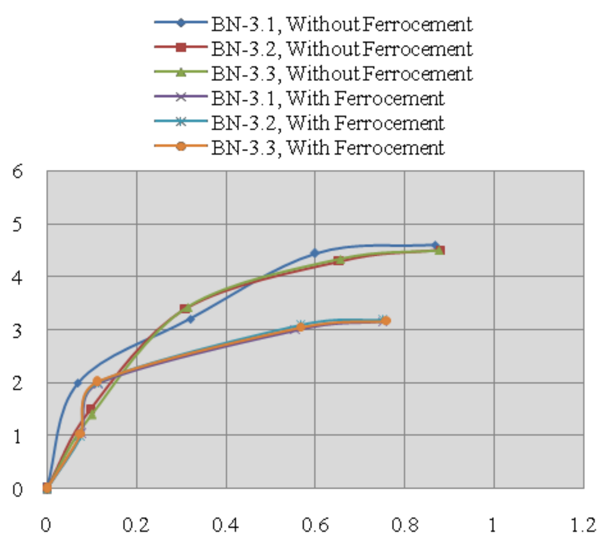


Fig 5: Load (kips) Vs Deflection (inch) Curve of Beam Set 3

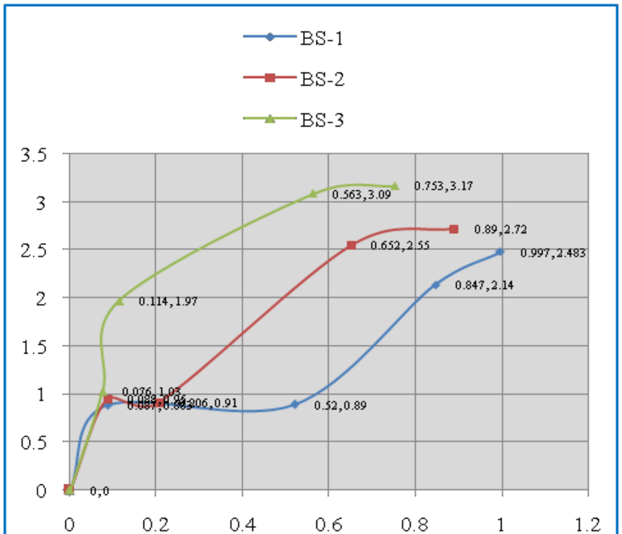


Fig 7: Comparison of Load Vs Deflection Curve Among Different Layer Ferroecement Thickness

VI. TEST RESULT ANALYSIS & DISCUSSION

In the experiment of three sets of R.C.C. beams were tested until the beams want to fail. The load corresponding to an allowable central deflection of 1.12 inch (span 5.5′) was obtained from a load deflection curve as 5000lb. From Table [2] to Table [7] present the comparison of cracking load, ultimate load of three set beams before and after repairing. From Fig [3], [4] and [5] we can see that before repairing the beams with a gradual increase in load, there is a considerable increase in deflection for all beams. These graphs also show that after repairing with ferrocement there is increase in deflection but the load is not increasing by that rate. Fig [3] shows the one layered ferrocement beam

in which the rate of load increasing pattern is not so gradual, Fig [5] represents the beam with two layers in which the rate of load increasing pattern is approximately gradual and Fig [4] represents that the rate of load increasing pattern is gradual. A relationship between average ultimate load and maximum deflection is represented in Fig[6] and Fig [7] shows the comprising performance of these repaired beams. So now, from this analysis one point has been noticed that repaired beam set 2 and 3 give reasonable strength as repaired beam and between them repaired beam set 2 has uniformity because of gradual performance. This experiment also creates a relationship between cracking load and cracking moment, ultimate load and ultimate moment.

Table 8: Results from Test for Cracking and Ultimate Loads and Moments of the Specimen

Specimen No.	Reinforcement ratio (%)	Load at first hair crack (kips)	Cracking moment (kip-inch)	Deflection at first hair crack (inch)	Ultimate load (kips)	Ultimate Moment (kip-inch)	Deflection at ultimate failure (inch)
	Wire Mesh	(test)	M_{cr} (test)	(test)	(test)	Mu (test)	(test)
Without ferrocement Layer (Before repairing)							
BS 1	0	2.50	41.25	0.035	5.10	82.50	0.667
BS 2	0	1.25	20.625	0.079	4.00	66.00	0.790
BS 3	0	1.50	24.75	0.097	4.50	74.25	0.879
With ferrocement Layer (After repairing)							
BS 1	0.082	0.88	14.52	0.090	2.50	41.25	1
BS 2	0.398	0.98	16.17	0.037	2.74	45.21	0.88
BS 3	0.450	1	16.50	0.076	3.05	49.50	0.750

VII. CONCLUSION AND RECOMMENDATION

The results of tests performed in this study indicate that significant change is occurred at ultimate load, cracking load and deflection. Due to the failure, the load carrying capacity of the beam is relatively less, to overcome these problems ferrocement layer can be used and hence the result shows that increasing the load carrying capacity and decreasing deflection. In the point of view this project, reducing the percentage of the cost. Therefore this method is advantageous for particular cases where the existing beam is strengthening for reusing.

The study on strengthening reinforced concrete beam overlaying ferrocement has the following utilization in future:

a) The damaged reinforced concrete beam can be repaired using ferrocement overlay as to restore performance with respect to service and ultimate load levels.
b) To improve structural behavior the reinforced concrete beam can be strengthening using ferrocement overlay.
c) In particular cases where the beam is designed for a load less than the design load due to construction error it can be improved to design load using ferrocement overlay.
d) The cost of reinforced concrete beam by ferrocement overlay instead of mortar and plasters not economical.

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